International **A**dvanced **R**obotics **P**rogramme

New Zealand Status Report on Advanced Robotics

20th **J**oint **C**oordinating **F**orum

October 2001

Werner Friedrich (ed.)
Industrial Research Ltd.

1. Introduction

This document is a status report prepared for the 2001 Joint Coordinating Forum (JCF) meeting of the International Advanced Robotics Programme (IARP). An overview of current activities in robotics research and development in New Zealand is presented. The report includes a brief summary of current funding schemes. The main content of this report is based on project information of advanced robotics supplied by research groups active in government funded research and industry funded projects. Emphasis has been placed on unreported work.

2. Research Environment

2.1 Government goals

As a free market economy, innovation in New Zealand is driven by both public and private investment. Given our small size and large distance from most markets, New Zealand's wealth also depends on how well we make use of our comparative advantages - such as natural resources and our "can do" attitude. To improve the international competitiveness of New Zealand's enterprises we need to support research to develop new technologies, the skills for applying these technologies; and processes for capturing value from commercialising these technologies.

The Ministry of Research, Science and Technology MoRST is a New Zealand Government Department which develops research and innovation policies and manages the publicly funded part of the RS&T system on behalf of the Government. MoRST works at the high level of policies, strategies and statistics. It contracts other agencies such as the Foundation for Research, Science and Technology to manage the actual funding of research and innovation projects.

New Zealand researchers are a key part of a national "innovation system" which includes businesses carrying out R&D, learning organisations turning out skilled people, and flows of information and investment. This year the government will invest about $620 million in research and innovation including $474 million in Vote: Research, Science and Technology.

Available funding is categorised in the following four major goals as follows:

> ***Economic goal*** (43% of available funds) - Transforming our economy through innovation depends on technically-skilled and entrepreneurial people developing and commercialising new products, processes and services.
>
> ***Knowledge goal*** (25%) - Modern economies and societies generally place a high value on basic research for creating new knowledge and ideas. More innovative and entrepreneurial people with the ability to create new knowledge are required to respond to New Zealand's changing needs, and support our capacity to innovate. They are a well-spring for new ideas to help transform our economy and society.
>
> ***Environment goal*** (18%) - New Zealand's unique environment is a vital part of our heritage, culture and quality of life. Maintaining these environments depends on our understanding of them and the development of policies and management systems to ensure sustainability. These areas include oceans policy, climate change, biodiversity and bio-security..
>
> ***Social goal*** (10%) - Investments under this research goal generate knowledge about a wide range of factors that can be used to improve social well-being in New Zealand. This includes investment in health, humanities, Maori development and social science areas.

With the exception of the social goal, advanced robotics could contribute to three of the four specified goals by commercialisation of innovative robotic products such as meat robotics, by creating knowledge through application developments and education on advanced robotics and by using advanced robotics for environmental monitoring,

2.2 Funding schemes - update

The following funding schemes are administered by the Foundation for Research, Science and Technology FRST:

Grants for Private Sector Research provide funding for small and medium-sized businesses to undertake research & development projects.

The New Economy Research Fund invests in excellent investigator-initiated projects with the potential to create new types of business for New Zealand.

Research for Industry Increases the competitiveness of sectors such as New Zealand's food and fibre industries, manufacturing and service industries, and in infrastructure such as communications, energy, water and waste to support research for industry**.** This scheme provides a $171million fund and is a main funding source for applied robotics research.

The **Technology New Zealand** scheme invests in building the technological capability and capacity of New Zealand's small and medium enterprises. The scheme includes:

- TechLink - focuses on improving the adoption of new technologies;
- Graduates in Industry Fellowships - places students in a commercial environment;
- Technology for Business Growth (**TBG**) - helps companies to develop innovative technologies. Grows businesses by increasing their ability to adopt and learn to use new technology and innovation.

2.3 Providers of Robotics and Automation Research

The main providers of robotics research in New Zealand are universities and one crown research institute - Industrial Research Limited, the largest recipient of funds in this area.

Universities

New Zealand's seven universities offer a wide range of tertiary education studies, which include science in all cases and aspects of technology in most. Areas of specialty in science and technology at the various universities include agriculture and horticulture; biological, physical, earth, marine and environmental sciences; forestry; engineering; medicine and pharmacy; mathematics, statistics and computer science. NZ prime industries are potential application areas for advanced robotics.

Several universities have active groups of academic staff and postgraduate students who provide a fertile ground for new ideas and experimentation. The universities play a strong and valuable role in educating students in research techniques and in use of appropriate technologies.

Crown Research Institutes (CRIs)

Nine CRIs were established in 1992 as Government-owned businesses with a scientific purpose. Each institute is based around a productive sector of the economy or a grouping of natural resources. Crown Research Institutes (CRI's) in New Zealand are government owned research establishments, which operate as limited liability companies. The business of CRIs is thus a portfolio of long term research programmes funded by the Public Good Science Fund, and a range of contract research and development projects for commercial companies, both local and offshore. Many of the local commercial projects are partly funded by Technology New Zealand.

IRL works with a range of industry sectors with an emphasis on the manufacturing, processing, biopharmaceutical and energy sectors. Technologies are also developed which benefit the horticultural, agricultural and forestry sectors. These sectors present future opportunities for the development of advanced robotics applications. Industrial Research is active in sensor interfacing including processing, utilization & programming, in tele-robotics, in mobile robot coordination and in commercial R&D for example in meat robotics.

Robotics NZ

Last year a Robotics NZ initiative was established. Participants of this initiative include research organisations, manufacturers, integrators and end-users. The main strength of Robotics NZ lies in complementing robotics research and development resources for the benefit of New Zealand. All participants including the funding provider, the Foundation for Research and Technology (FRST), have welcomed the initiative.

New Zealand has already demonstrated its ability to build sophisticated robotic systems, such as the world-leading technology designed for the meat industry. Robots also proved viable in the production and processing of food and fibre products as they substantially reduced labour intensive production, particularly where high quality is required and where the work was highly repetitive, injurious and hazardous. By focusing our R&D capabilities on a common goal, and with the support of manufacturers and users, New Zealand could establish itself in a world leading position in selected niche areas of robotics.

The Robotics NZ initiative has progressed and is currently formulating a long term research portfolio in conjunction with funding agents.

Current robotics activities from submissions and publications of individual groups are summarised below.

3. Summary of activities from robotics research groups

This section summarises current not reported activities and is based on submissions and publications from individual research groups.

3.1 University of Auckland

Department of Mechanical Engineering, Manufacturing Systems Group
Contact: Dr Enrico Hämmerle, Assoc. Prof. Des Tedford

The newly installed KUKA robot KR15/2, which forms the heart of the robotic cell and the simulation and off-line robot programming software tools from DENEB provide the backbone of the group's prototype environment. This is complemented by an older ASEA IRB6 which is used as the hardware skeleton for the development of a new intelligent robot controller. New projects in 2001 include the robotic jointing of composite materials and vibration testing of golf club shafts (Figure 1).

Figure 1 Vibration testing of golf clubs

The primary interest at this stage of the robotic jointing of composite materials is to determine the feasibility of the process and identify whether there is significant difference in the quality and consistency of joints made by the robot as compared to joints made manually. Standard test composite coupons are joined manually and by the robot, and tested on the Instron machine for tensile strengths.

The testing of golf club shafts attempts to create a reliable robotic means of measuring the vibrations felt in the hands of a golfer. Three different methods were used for the vibrational analysis involving strain gauge, piezo-electric force sensors and impact hammer tests to compare three different golf club shafts and an insert.

Department of Electrical & Electronic Engineering
Contact: Dr Bruce McDonald

Figure 2: Mobile robot platform

Activities in the Electrical Engineering Department are centred around the newly acquired mobile robot platform (Figure 2). Mobile robots often work in uncontrolled environments where artificial landmarks are not available. The robot must navigate through such an environment using sensory data to offset accumulated odometry errors. A central swath through an omni-directional image is processed to provide a one-dimensional sequence of tokens, and matched against a set of previously taken reference images. Triangulation is used to estimate the robot position and orientation during matching, and the best result is taken as the cur rent robot position. Methods of choosing reference image sites are discussed, including generalised Voronoi diagrams.

A vision-based indoor mobile robot localisation algorithm was developed that does not require historical position estimates. The method assumes the presence of an *a priori* map and a reference omni-directional view of the workspace. The current directional image of the environment is captured whenever the robot needs to relocalise. A modified hue profile is generated for each of the incoming images and compared with that of the reference image to find the correspondence. The current position of the robot can then be determined using triangulation as both the reference position and the map of the workspace are available. The method was tested by mounting the camera system at a number of random positions in a 11.0m by 8.5 m room. The average localisation error was 0.45 m. No mismatch of features between the reference and incoming image was found amongst the testing cases.

A monocular vision system has been added to the existing robot in order to improve its navigation performance. Amongst the two main layers in the vision--based navigation system, the lower level image processing module is the focus of this paper. The image processing module is responsible for the extraction of straight lines with various orientations. A range map is first generated from the input image stream. The edges are then extracted using a non-maximum suppression technique. It works reasonably well for a series of test images. The navigation module is undergoing active development. The implementation of a vision-based localisation unit is the priority at this moment.

3.2 University of Canterbury

Department of Mechanical Engineering
Contact: Assoc. Prof. Reg Dunlop

Recent activities include the development of a 6 legged walking robot with a multi-criteria system for hexapod gait generation. The simple algorithm allows full omni-directional manoeuvring as an emergent property. For forward walking results two neural network and distributed systems have been developed. These are based on biological observations of inter-leg influences, adopting a stable periodic gait on flat services. When a leg is restricted the leg changes from stance to swing bringing it to a less restricted configuration while contributing to locomotion. Exponentially increasing fields are used to establish a measure of leg restriction according to several conditions including allowable joint angles, distance from the home position and the proximity to adjacent legs. The system is easily implemented in conventional software and has been verified with experimental results demonstrating omni-directional control of a small six-legged robot (Figure 3).

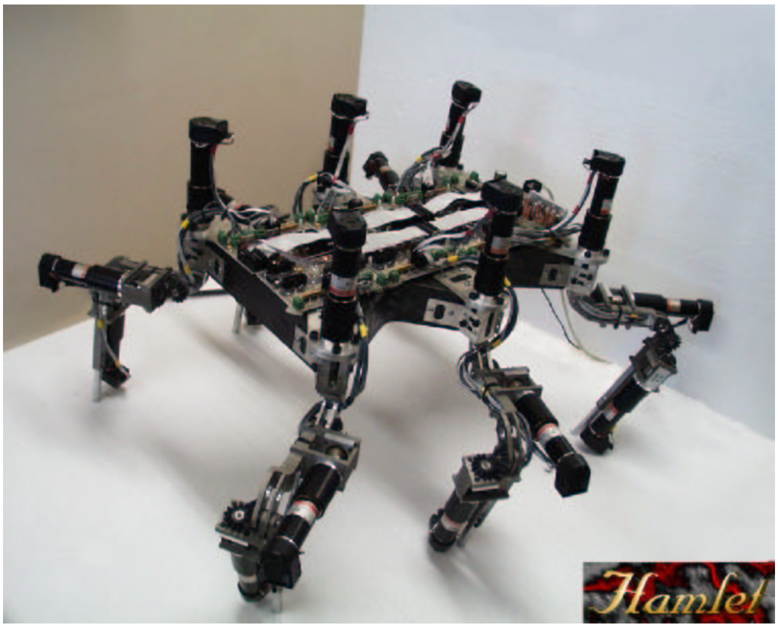

Figure 3: University of Waikato's 6 legged walking robot

Carbon fibre protective boots are being constructed to encase the load cell and motors, to protect them from damage when they hit obstacles. These boots will be equipped with a switch to indicate when a collision has occurred. An inclinometer will also be attached.

Compliant control has been demonstrated with scope for stability improvement when contacting hard surfaces by non-linear schemes. Damping of the position controlled subsystem is also experimented to improve stability under compliant control while still achieving acceptable performance when not in contact with the environment.

Further research can be carried out to show that the use of horizontal foot force information to make the feet of a small hexapod walker compliant. This may improve handling of changes in the environment caused by the robot walking over it. Global force control may not be necessary to achieve robust, reliable walking at least for small robots. A 'soft' algorithm rather than a CPG controlled algorithm will be used to provide robust gait generation for the robot.

3.3 University of Waikato

Department of Electrical Engineering
Contact: Dr Dale Carnegie

Waikato University is active in autonomous robotics and developed a mobile robot, named MARVIN (Figure 4). The machine is approximately 1.7m high, and weighs around 70 kg. The motor and transmission system obtained from an electric wheelchair. Positioning information is provided by shaft encoders and through a front facing laser-range finder based on a triangulation system with the ability to scan 360 degrees with an accuracy of about 5cm. A pair of lead acid car batteries satisfy the power requirements

The robot is controlled by a Pentium III processor which interacts with motors and sensors via DAQ card. .LabView is employed to program motion and sensing activities. LabView provides a graphical means of designing Virtual Instruments (VIs) that can appropriately condition the required input/output signals.

Top-level control for task planning/facilitation can then be coded in MatLab, which can control and operate the LabView VIs in an autonomous (human independent) fashion. This control platform is ideal for our various field robotics activities.

Figure 4: Mobile robot: Marvin

Figure 5: Waikato's ROV

An ROV (Remote Operating Vehicle) was obtained in a non-operational form from Oceaneering in Singapore. It was transformed into an semi-autonomous, functioning underwater device (Figure 5).

The vehicle is a 2 horsepower electric, tethered ROV. The rebuilt system incorporates additional components selected to provide the vehicle with enough onboard intelligence to become autonomous. A GA-5VMM motherboard with an AMD K62 500 processor is utilised for its small size and processing power. An IOTech 2005 Data Acquisition card (DAQ) provides the link between motors, sensors, and control cards. A D-Link DE-528 Series network card connects surface console to vehicle by coaxial cable. A Phillips Universal Serial Bus (USB) PC ¼" CCD camera with pan/tilt mechanisms is located in the central hull.

Currently, the ROV displays the compass, pressure, tilt sensor, and camera readings to a surface console in real time. Digital outputs which activate lights, main drive motors, and manipulate the pan and tilt of the camera, are simply controlled by LabView icons.

3.4 Industrial Research Ltd

Automation Systems
Contact: Dr Richard Templer, Dr Werner Friedrich

Examples from research projects

Tele robotics

For most robotic applications, the robot executes a series of point to point movements along a predefined path. However when an application requires tracking of the object surface, contour following demands continuous adaptation of its path and complex articulation of the robotic arm. To overcome the resultant limitation in processing speed, a 3 DOF (degrees of freedom) compliant sensing tool was developed. It is contact based (tactile) with built-in sensors to detect surface geometry and compliance to maintain orthogonality with surface during contour following. Built-in sensors measure the degree of compliance and the robot corrects its position and orientation with respect to the surface. The adaptive controller derives a vector-based projection for the robot path based on sensory and user data. The principle has been demonstrated with a 4 DOF robot and simulated in 3D contoured surface involving a 6-DOF industrial robot.

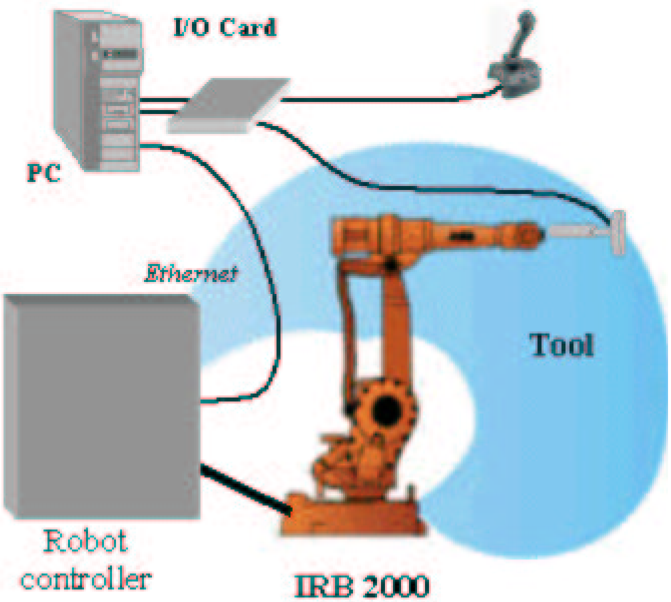

Figure 6: Integration of robotic system components

The technological demands of robotic contour following was addressed by introducing mechanical compliance to a specialised tool. With compliance, the traverse speed can be increased while the sensing data rate is reduced providing greater flexibility in terms of processing speed without being limited by process dynamic constraints. The simulation results demonstrated that the tool adhered to the surface continuously with the face plate normal to the surface during motion. The adaptive control was accomplished efficiently by a vector-based projection and prioritising method.

Cooperative robots

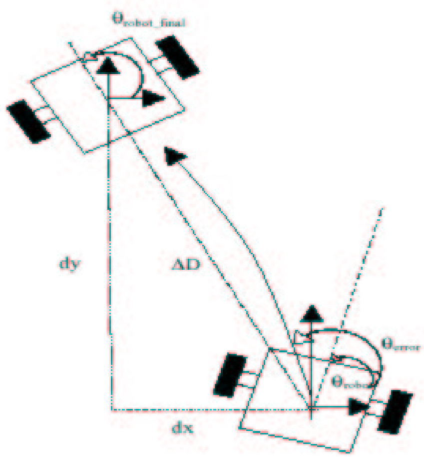

Figure 7: Steering control - example

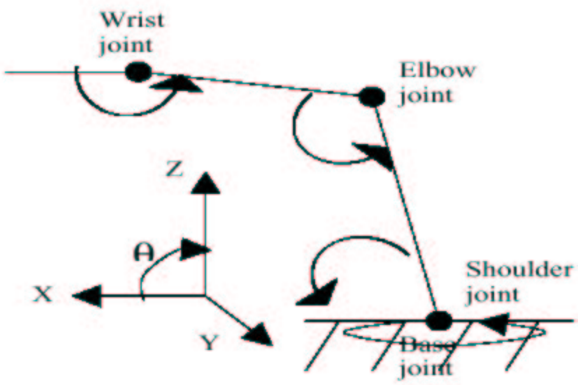

Figure 8: Robot joint configuration

A cooperating robot environment was created to allow two mobile robots to pick up an object simultaneously – one robot at either end of a long object. Multiple robots cooperating to share the workload allow increased generic handling and placement control. However, precise co-ordination between each vehicle and their respective manipulator is required to ensure that the object will be adequately supported.

A test bed was created to examine the physical cooperative and communicational demands. The experimental robots are two small scale wheel chair type mobile platforms with wheel encoders. Each platform supports a five axis robotic arm, motion control strategies and coordination techniques including object recognition and movement. Processed images from a ceiling mounted camera provide layout information for each object in the viewing area including robots and objects. Localisation is achieved by the combination of camera and wheel encoder data.

The task control is provided by three major modules including an image processing module to translate camera images into positional and layout information, a system control interface to control and view the current task status – implemented as a graphical user interface GUI and a robot control interface for each of the two robots to activate its vehicle and arm.

4. Commercially funded robotics developments – examples in meat robotics

Progress in meat Automation

Meat Processing in New Zealand is a major export industry. New Zealand is the world's largest exporter of lamb and fourth largest beef exporter. The industry is based around grass feed animals, very hygienic processing and innovative marketing.

Figure 9: Example robotic handling of large meat pieces

Meat processing automation in New Zealand has been funded by Meat New Zealand, an industry body that levies producers. As part of a portfolio of robotic automation projects with Meat NZ, local meat companies and equipment suppliers, a primal robotic handling system was developed for locating and handling large meat pieces (Figure 9). Success in New Zealand has lead to offshore research work by Industrial Research for the global red meat industry.

World-leading beef robotics

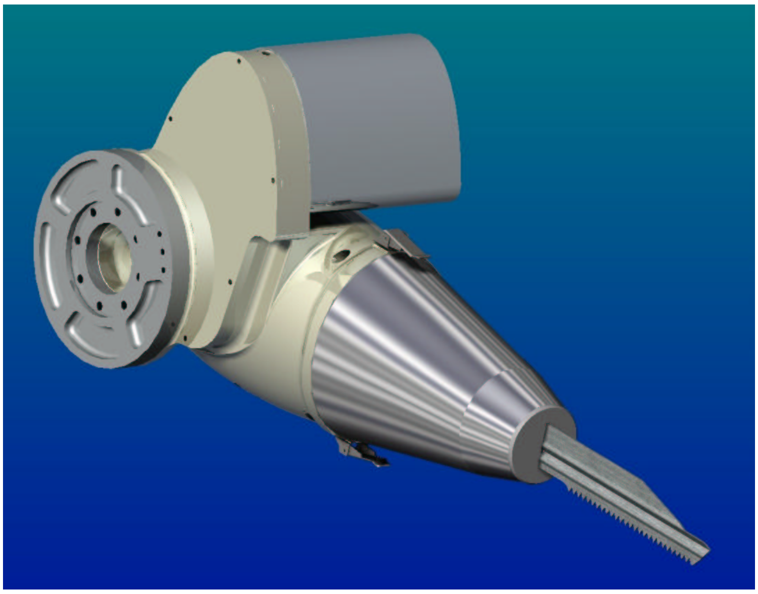

Figure 10: Cutting tool used in commercial beef robotics project

Together with a leading US beef producer and an Australasian partner, Industrial Research (Automation Systems team) completed two major beef robotics projects this year. The projects involved researching, developing, integrating and trialing fully automatic beef processing robots, the first robots of this type in the world. The new robots use advanced sensors and software to customise their cutting paths for each animal, and are capable of operating at over 400 animals per hour with success rates of more than 99 per cent. The completed projects are now being commercialised and a further four are underway.

5. Conclusions

New Zealand's small size and large distance from most markets, requires careful distribution of limited research funds including. The government is addressing these needs by a carefully adopted funding scheme which includes effective technology transfer.

The country has niche skills in robotics for the handling and processing of materials with high variability, such as meat, food and horticultural products. The motivation for automation in these industries is mainly economic production, improved health and safety for workers, and improved hygiene in food applications.

Significant progress has been made this year in research and commercial development. The universities are developing new skills in mobile robot control, for example the development of a ROV and cooperating robots. The meat processing robotics activity has achieved renewed international commercial recognition through integration and trailing of two fully automatic beef processing robots, the first robots of this type in the world.

The Robotics NZ initiative has progressed and is currently formulating a research portfolio in conjunction with funding agents. The main strength of Robotics NZ lies in complementing robotics research and development resources for the benefit of New Zealand.

6. Acknowledgements

Information for this report was gathered from

- New Zealand Ministry of Research, Science and Technology.
- New Zealand Foundation of Research, Science and Technology.
- Meat New Zealand.
- Industrial Research Limited.
- University of Auckland
  – Dept. of Electrical Engineering, Dept. of Mechanical Engineering.
- University of Waikato - Dept. of Physics and Electronics Engineering
- University of Canterbury - Dept. of Mechanical Engineering

Author Contact Details

Dr Werner Friedrich
Automation Systems
Industrial Research Limited
PO Box 2225
Auckland
New Zealand
Ph +64-9-303-4116, fax +64-9-307-0618
e-mail: w.friedirch@irl.cri.nz web site: http://irl.cri.nz